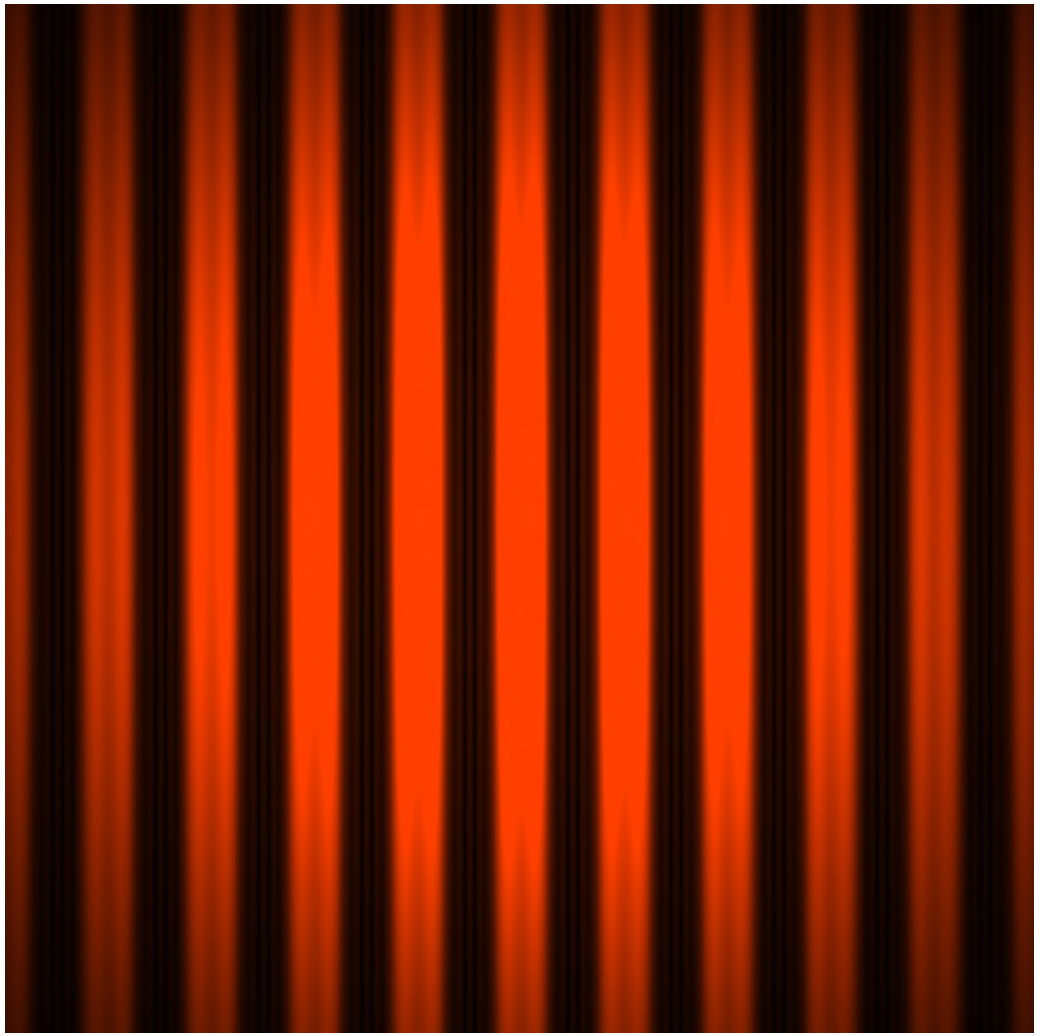
Demonstration of Abbe's Theory of Image Formation

Abstract



"*No microscope permits components to be seen separately if these are so close to each other that even the first light bundle created by diffraction can no longer enter the objective simultaneously with the non-diffracted light cone*." Ernst Abbe, 1873.

Within VirtualLab Fusion, we build up an imaging system, use chromium gratings as test objects, and demonstrate the theory of Ernst Abbe. On one hand, we change the grating period; on the other hand, we (keep the period) change the aperture at the Fourier plane, and investigate the influence on the image formation.

Modeling Task – Imaging with Varying Grating Period

How to simulate the image formation for grating objects in an imaging system, especially with the grating diffraction effects considered?

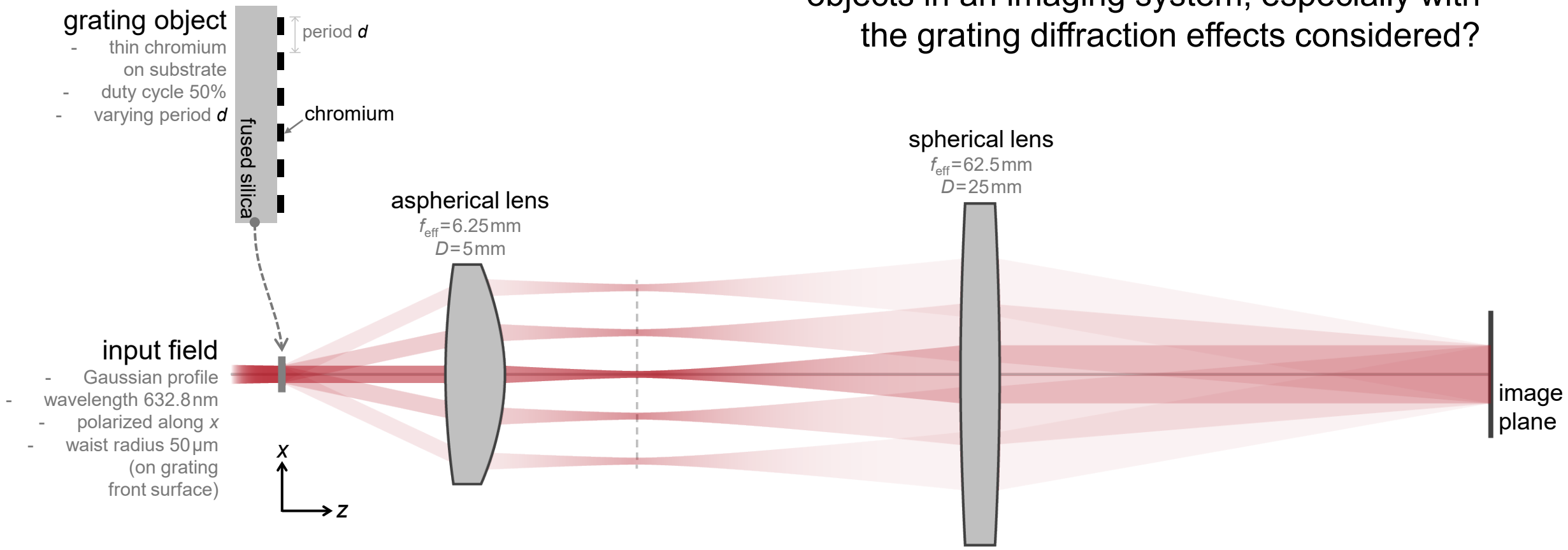


Image Formation Analysis

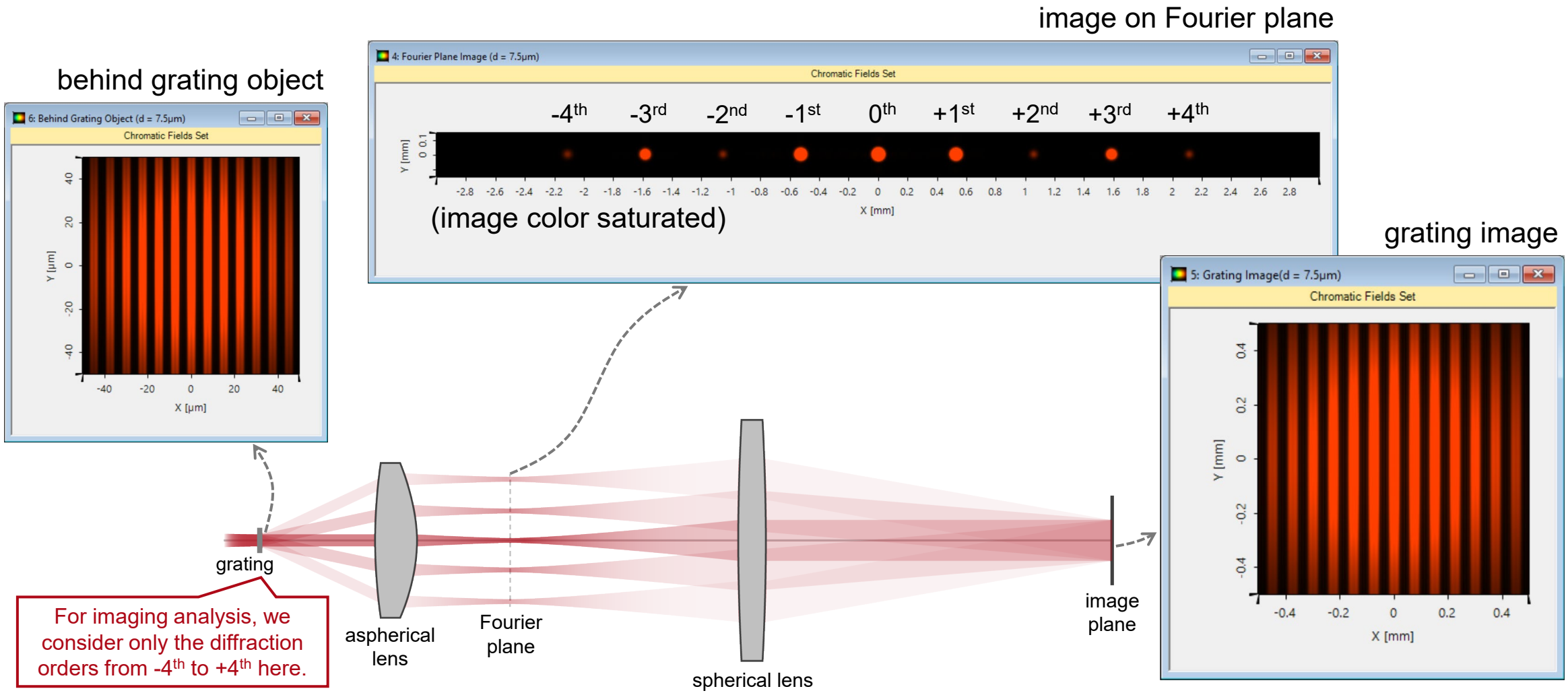
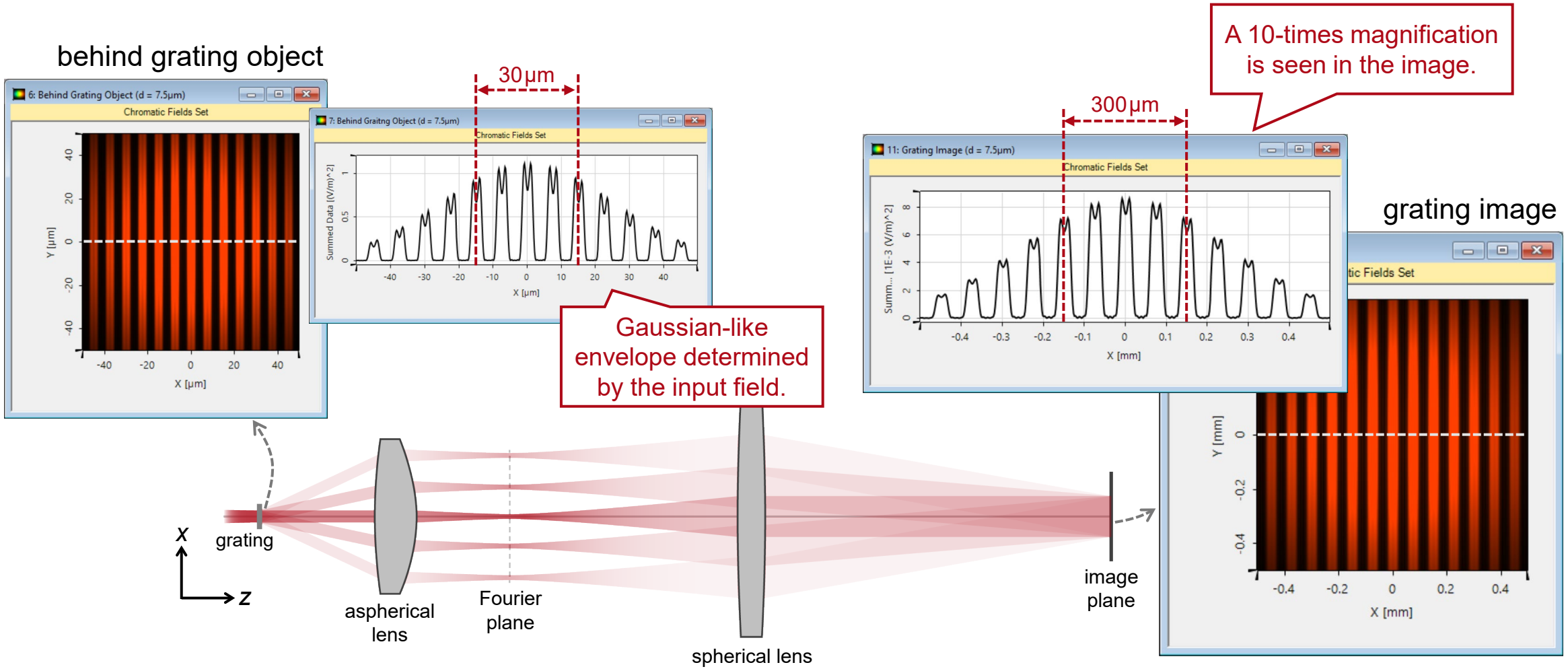
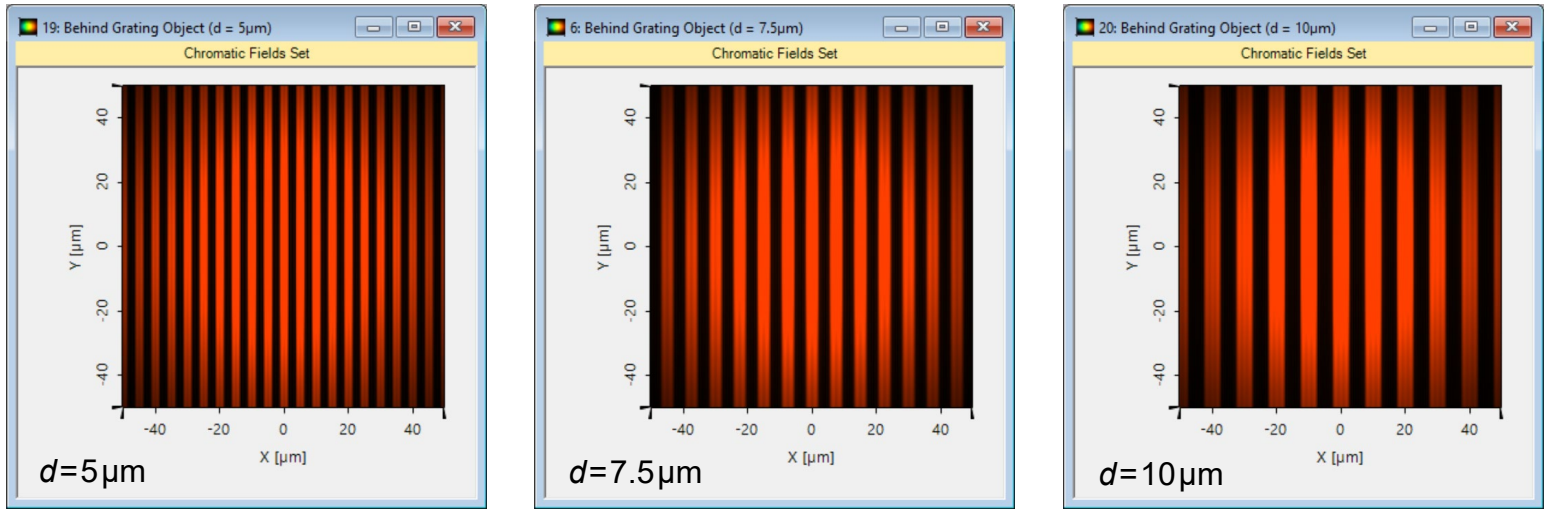
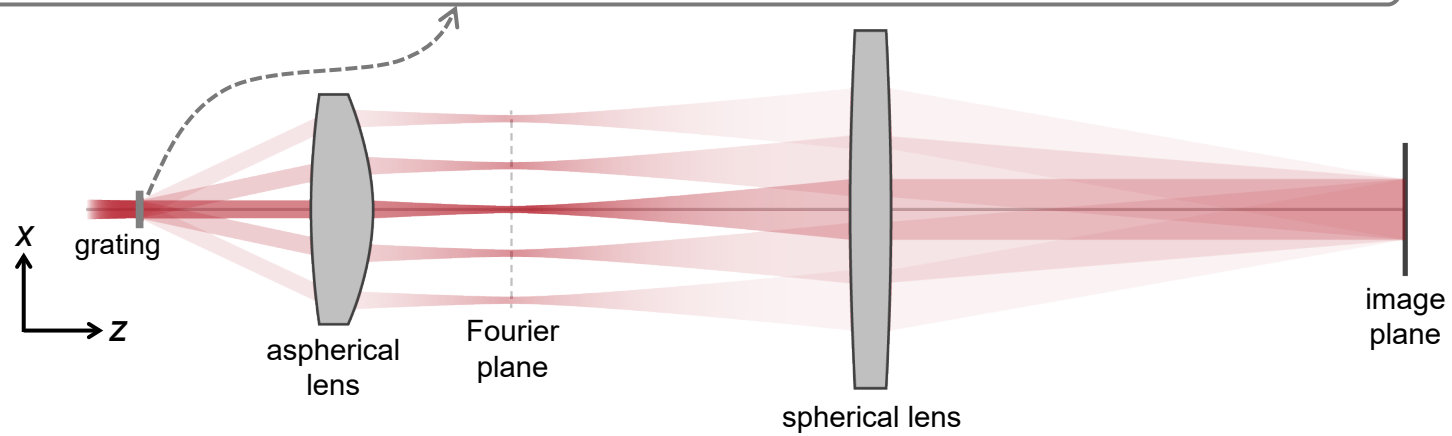


Image Formation Analysis



Behind Grating Objects with Different Periods

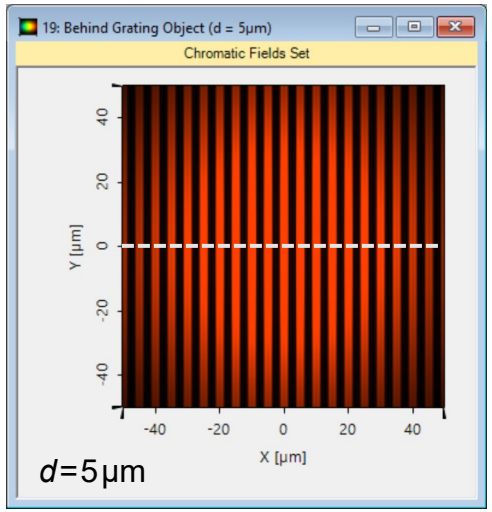


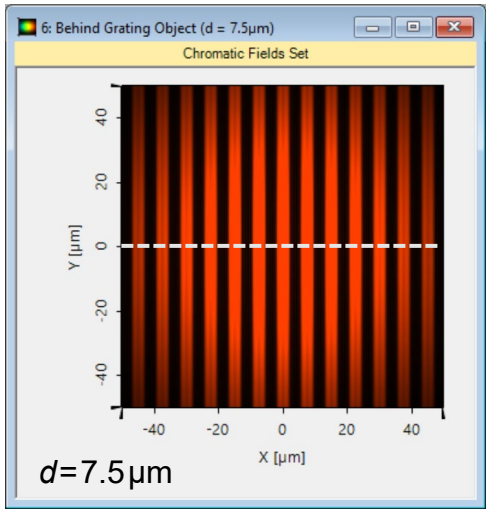


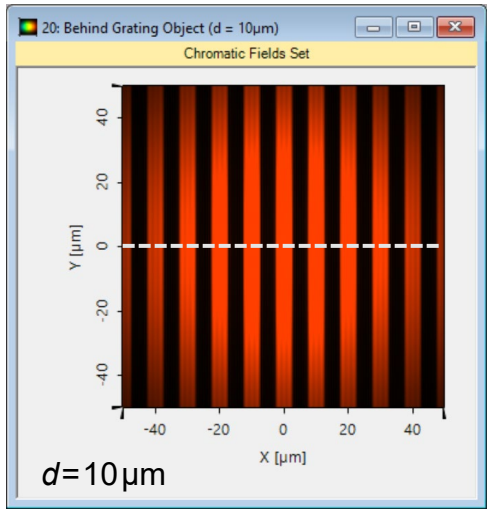
For imaging analysis, we consider only the diffraction orders that will enter the subsequent system:

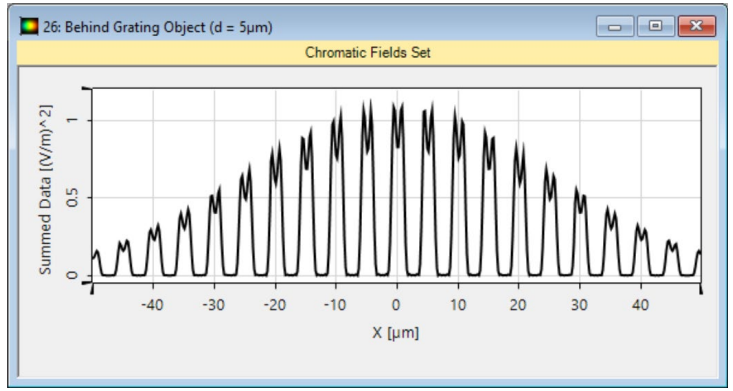
- d=5µm: -3rd to +3rd orders
- d=7.5µm: -4th to +4th orders
- d=10µm: -6th to +6th orders

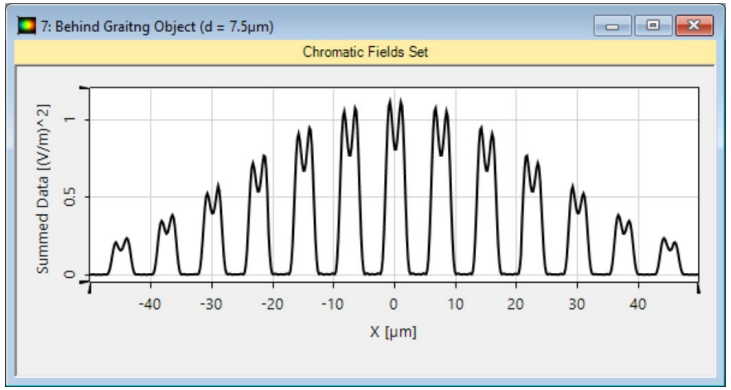
Behind Grating Objects with Different Periods

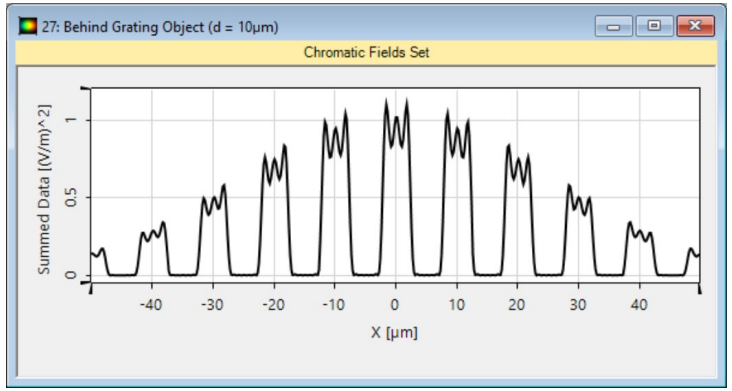




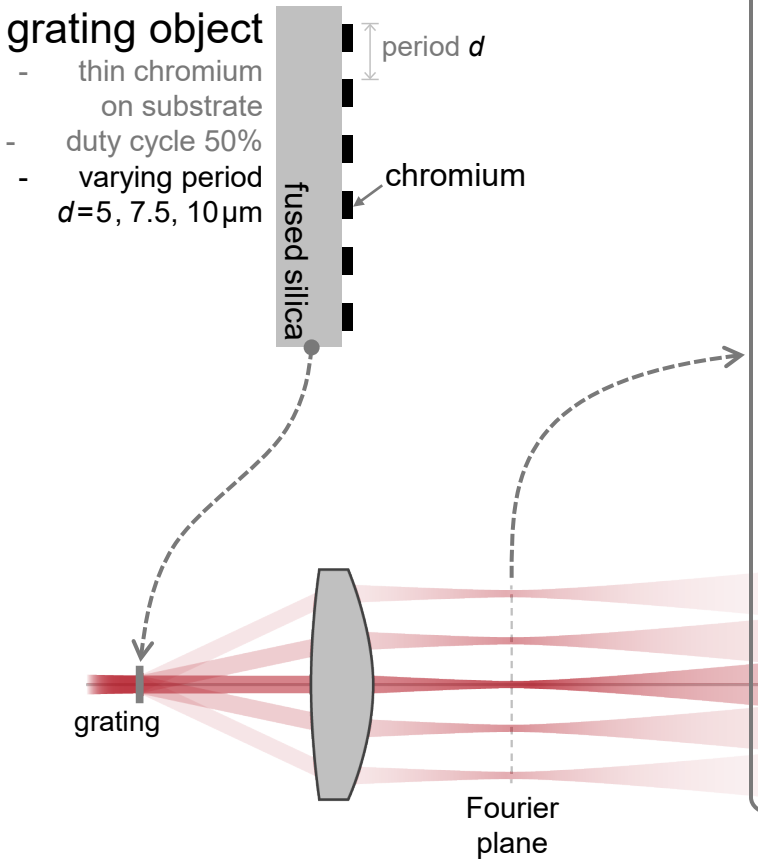




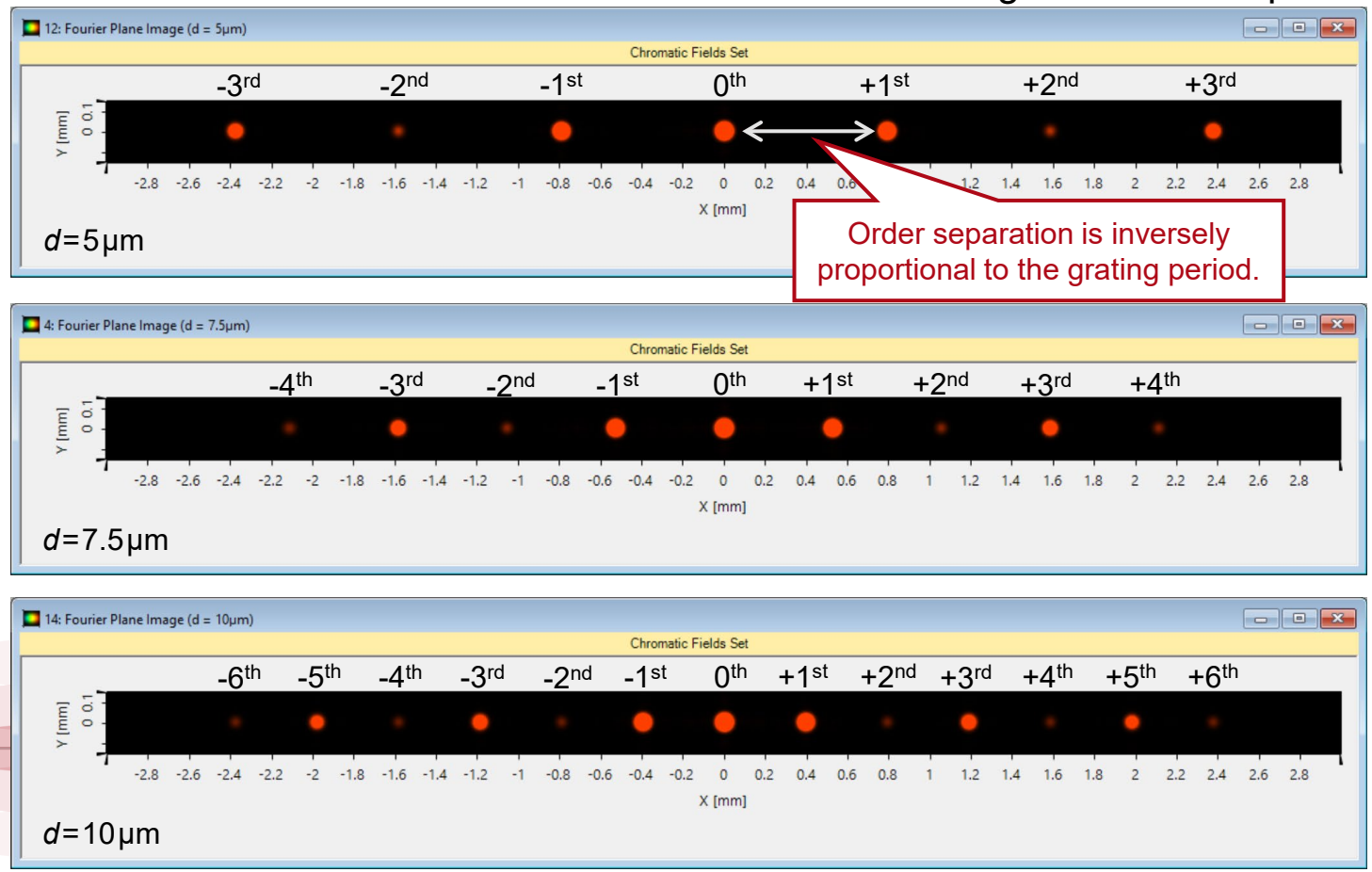




Fourier Plane Images for Different Periods

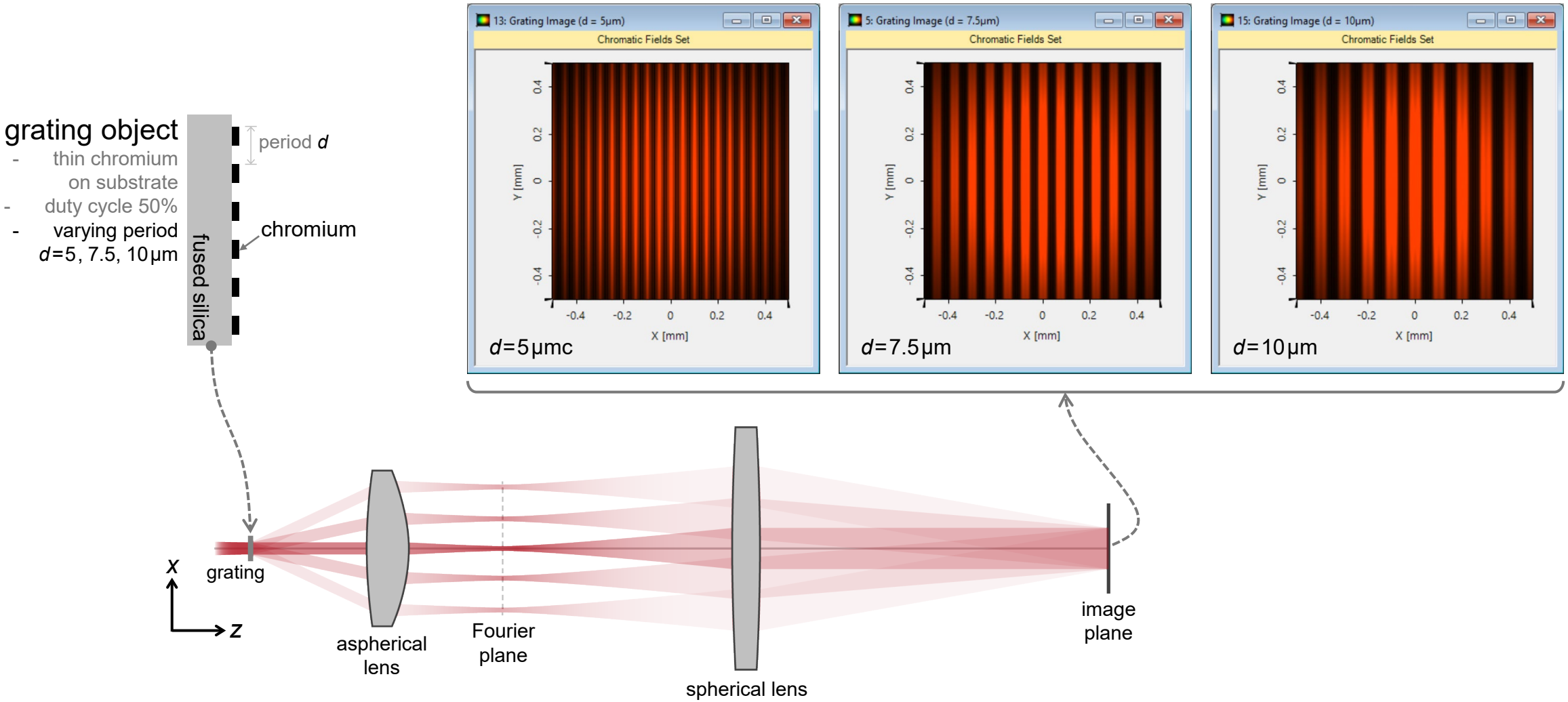


images on Fourier plane

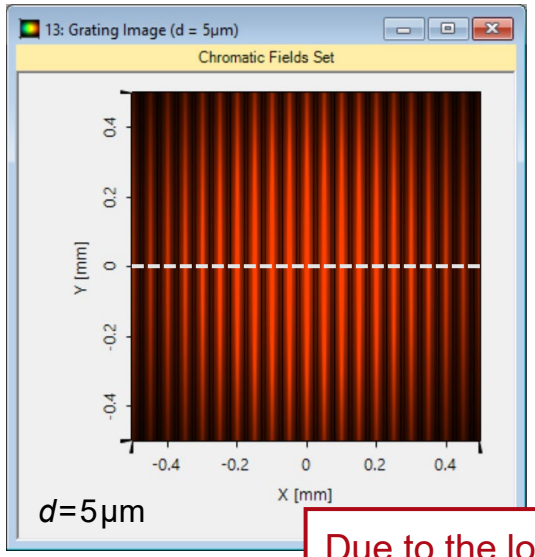


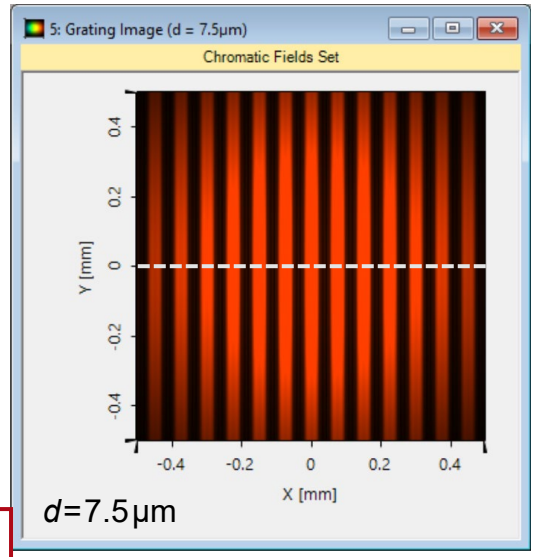
Grating efficiencies – corresponding to the spot brightness – are calculated by Fourier modal method (FMM, also known as RCWA).

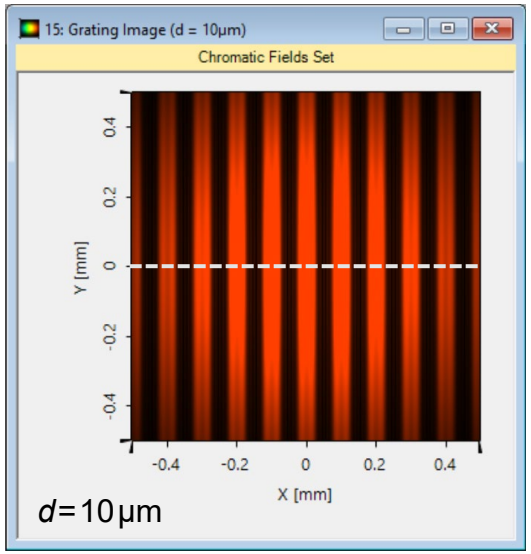
Grating Images for Different Periods



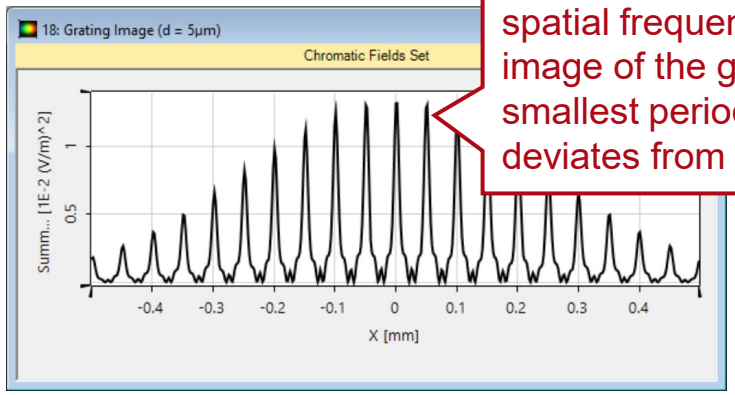
Grating Images for Different Periods

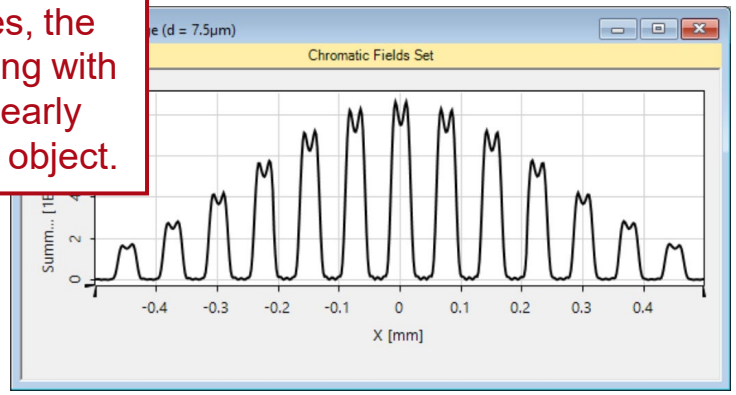


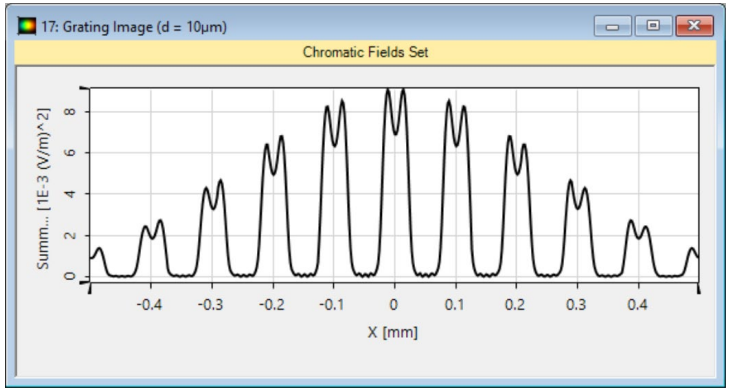




Due to the loss of high spatial frequencies, the image of the grating with smallest period clearly deviates from the object.

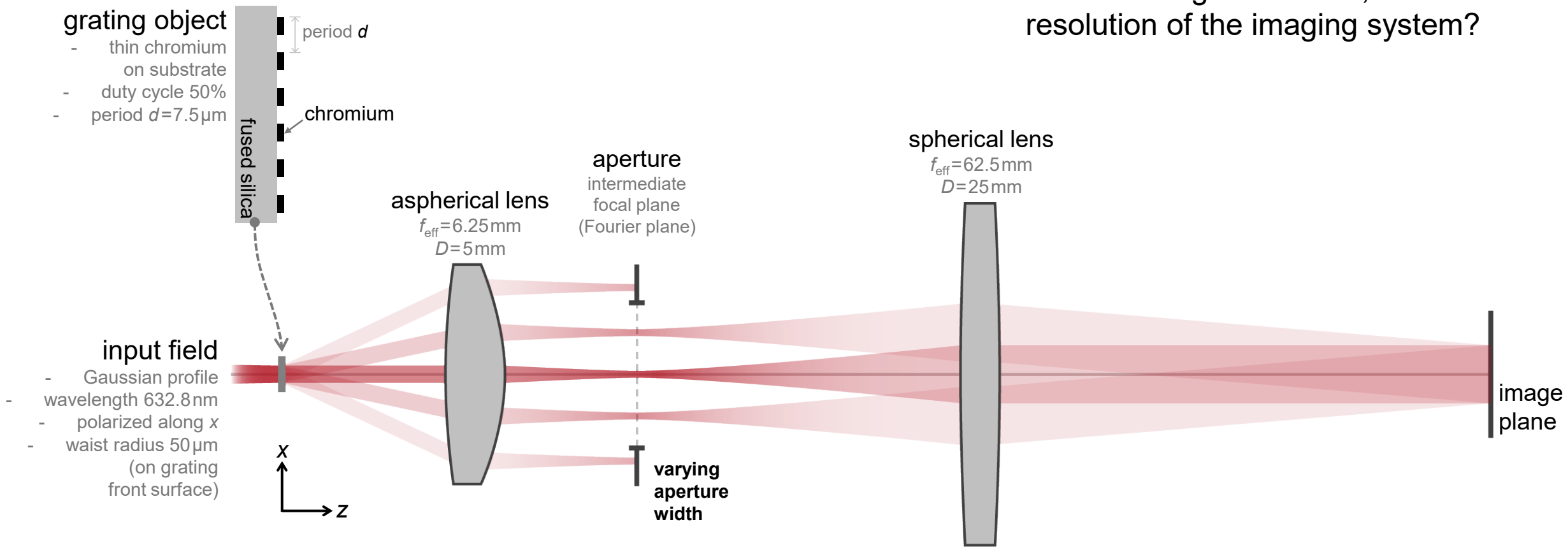






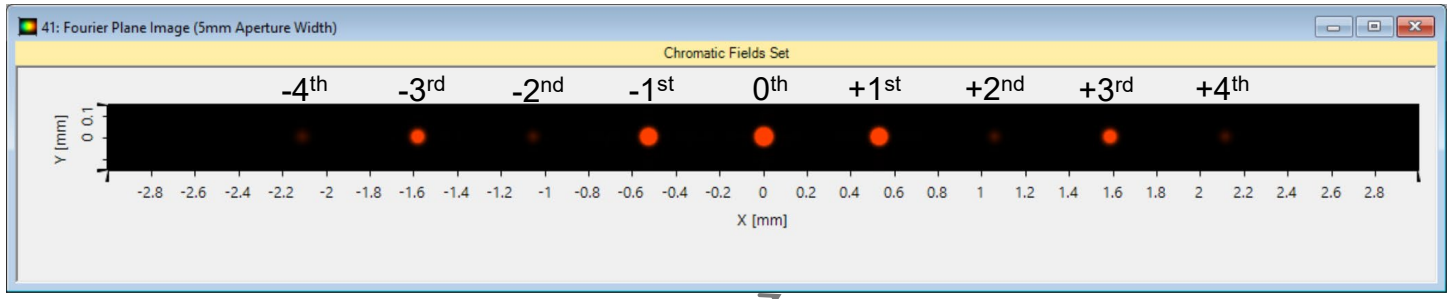
Modeling Task – Aperture Effect in Fourier Plane

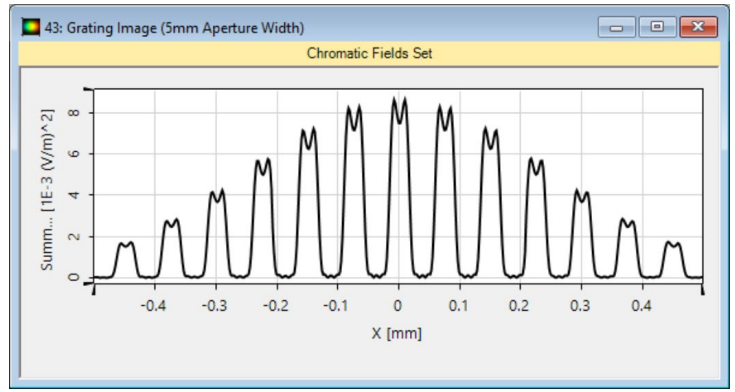
How can the aperture in the Fourier plane affect the image formation, and the resolution of the imaging system?

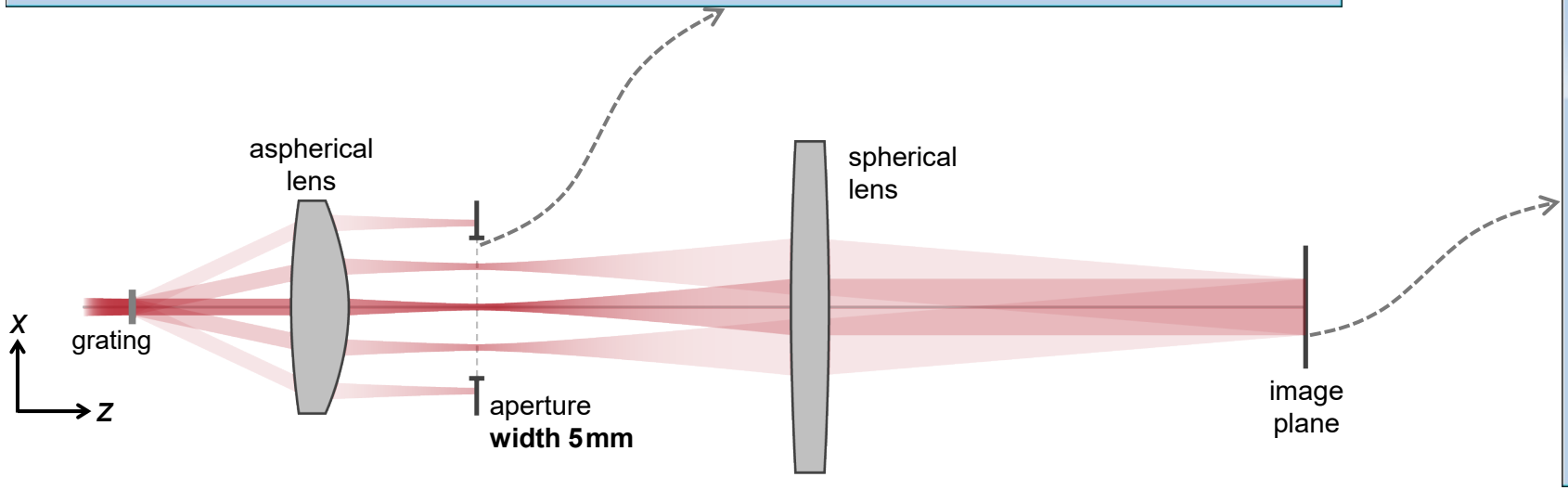


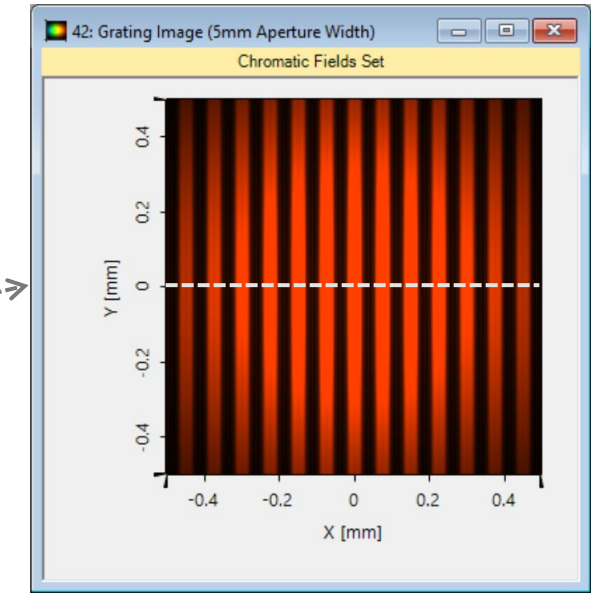
Aperture Width 5mm

images on Fourier plane behind aperture



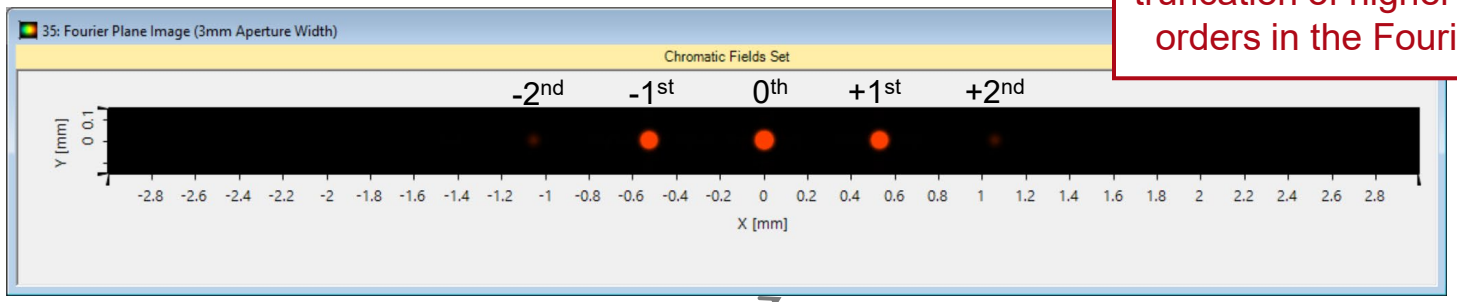




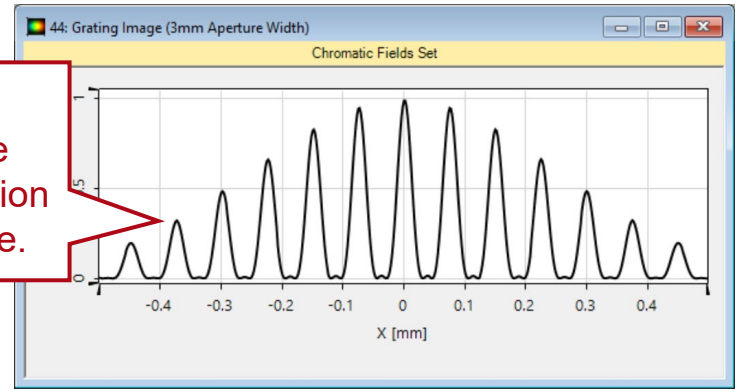


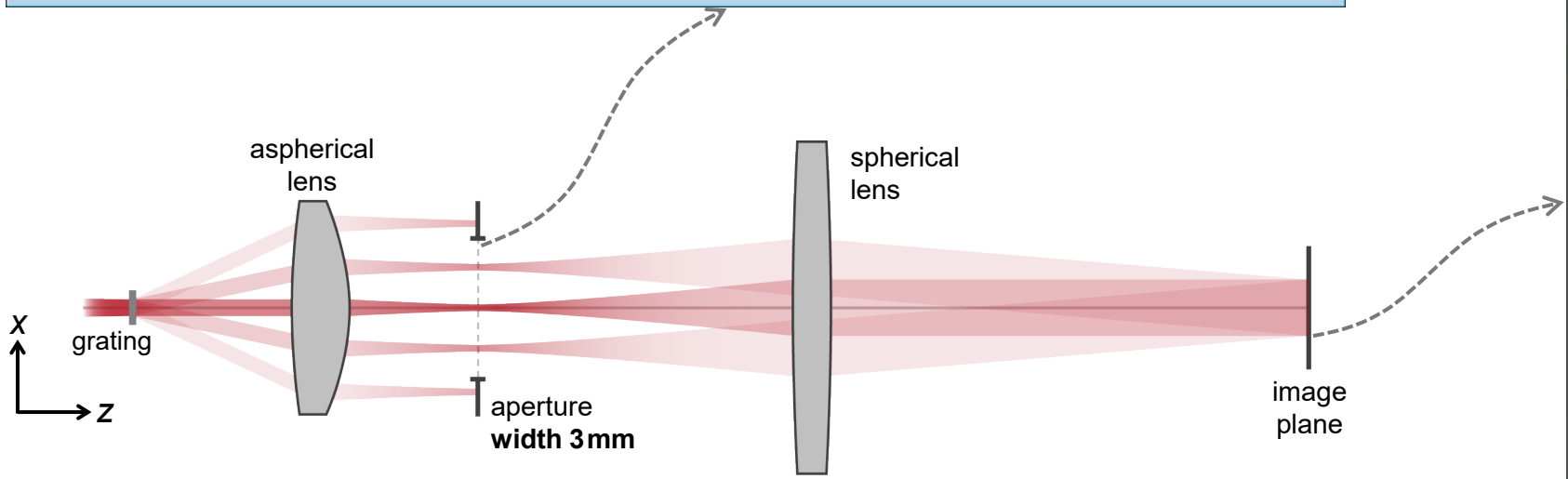
Aperture Width 3mm

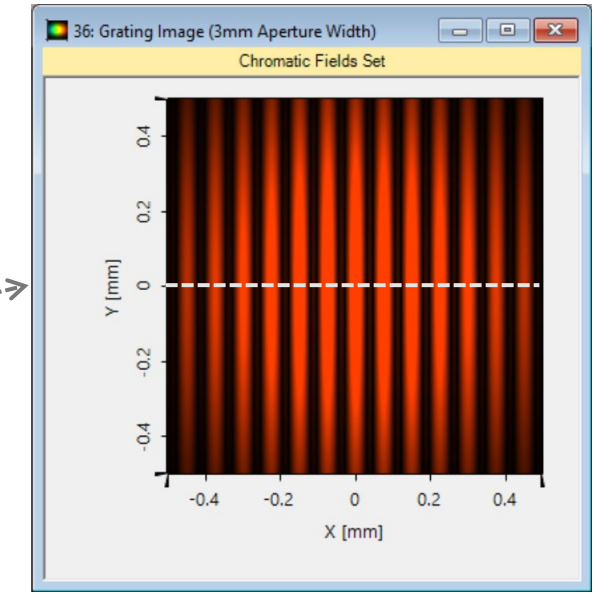
images on Fourier plane behind aperture



The grating image gets smoother because of the truncation of higher diffraction orders in the Fourier plane.

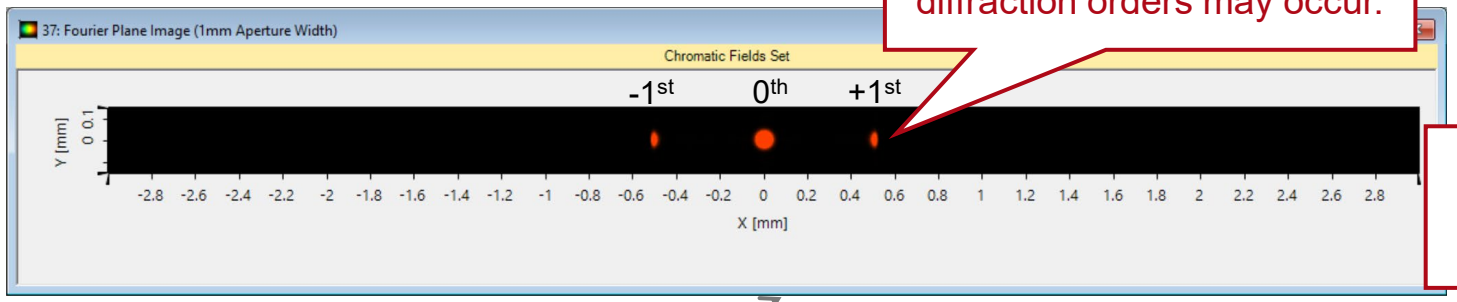




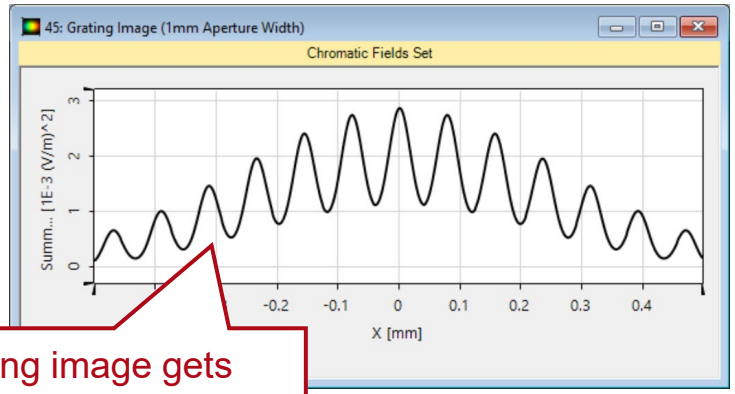


Aperture Width 1 mm

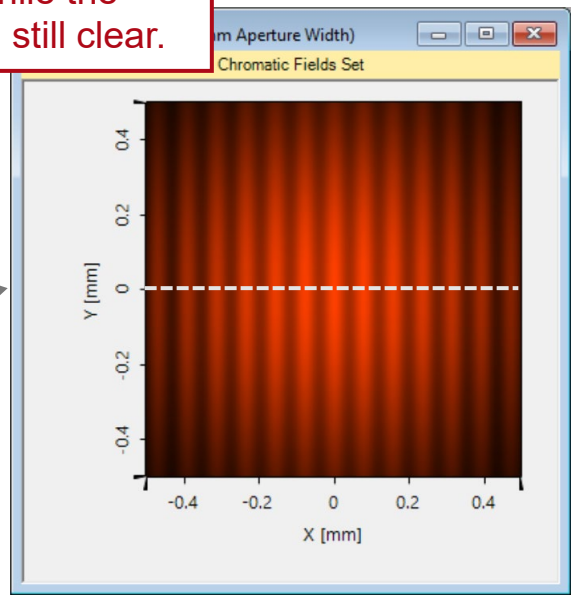
images on Fourier plane behind aperture

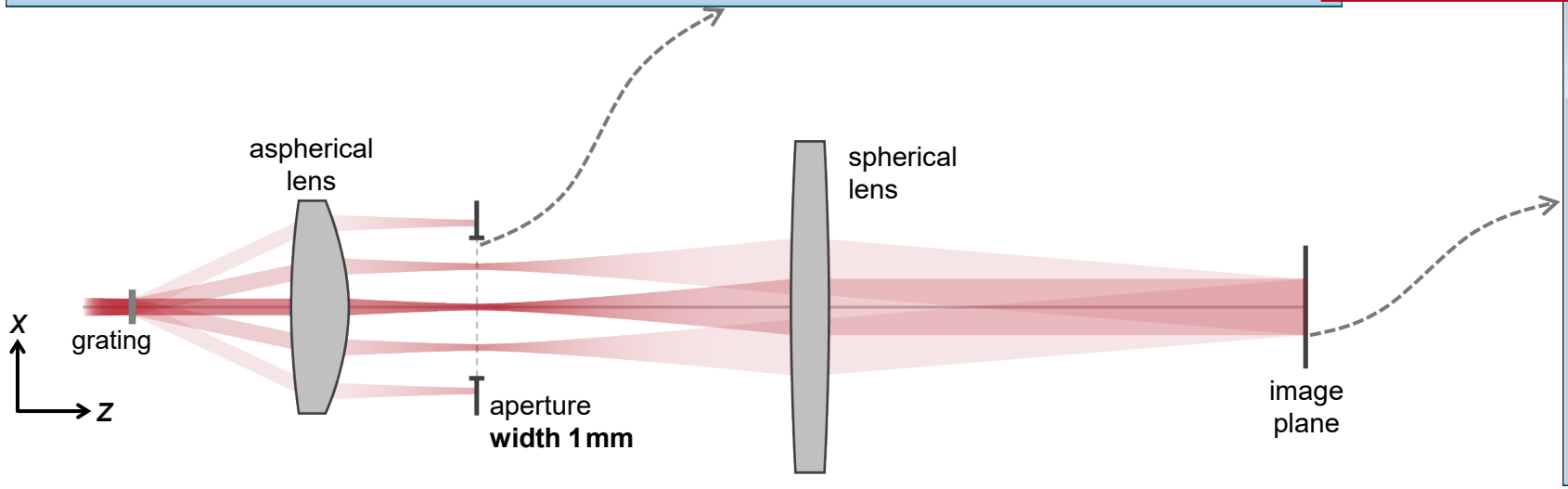


Partial truncation of certain diffraction orders may occur.



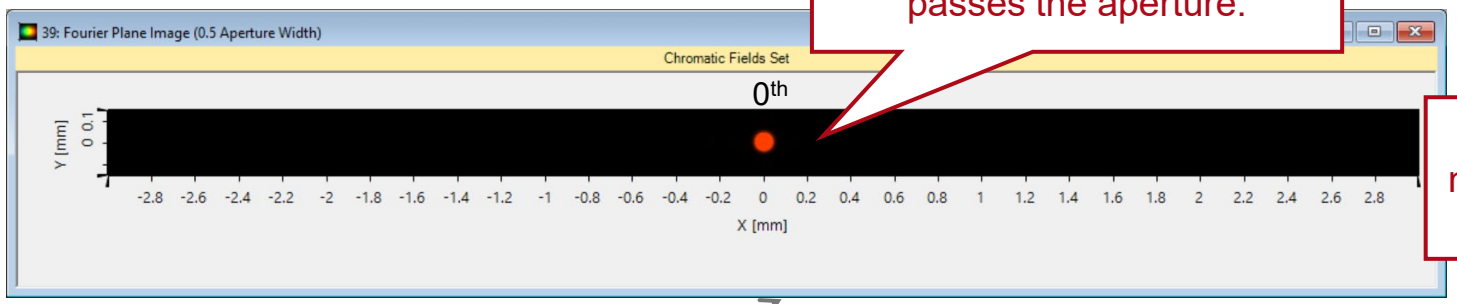
Grating image gets blurred while the periodicity is still clear.



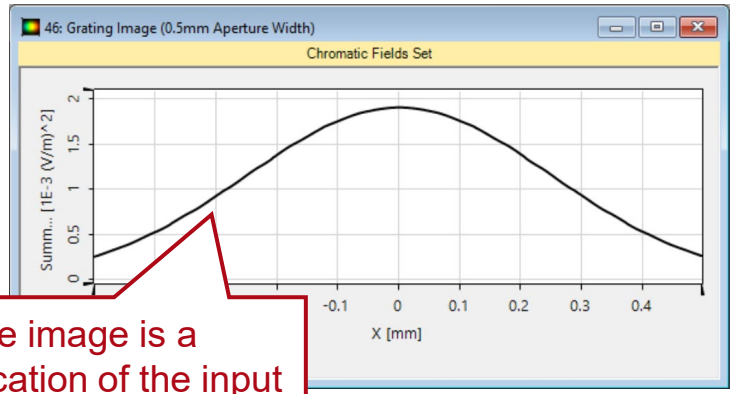


Aperture Width 0.5mm

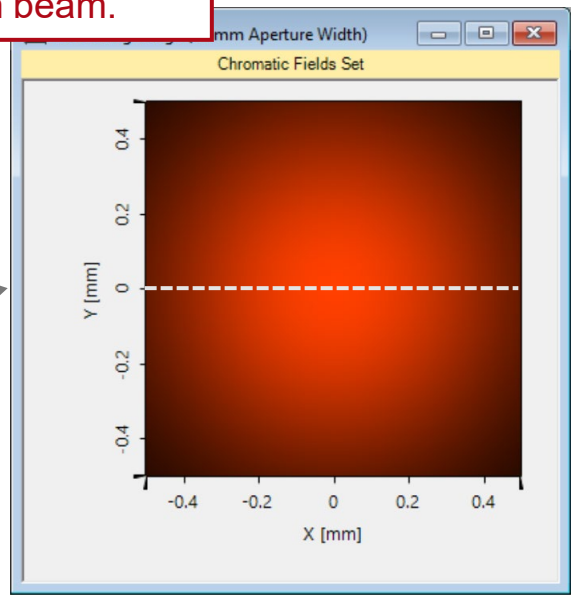
images on Fourier plane behind aperture

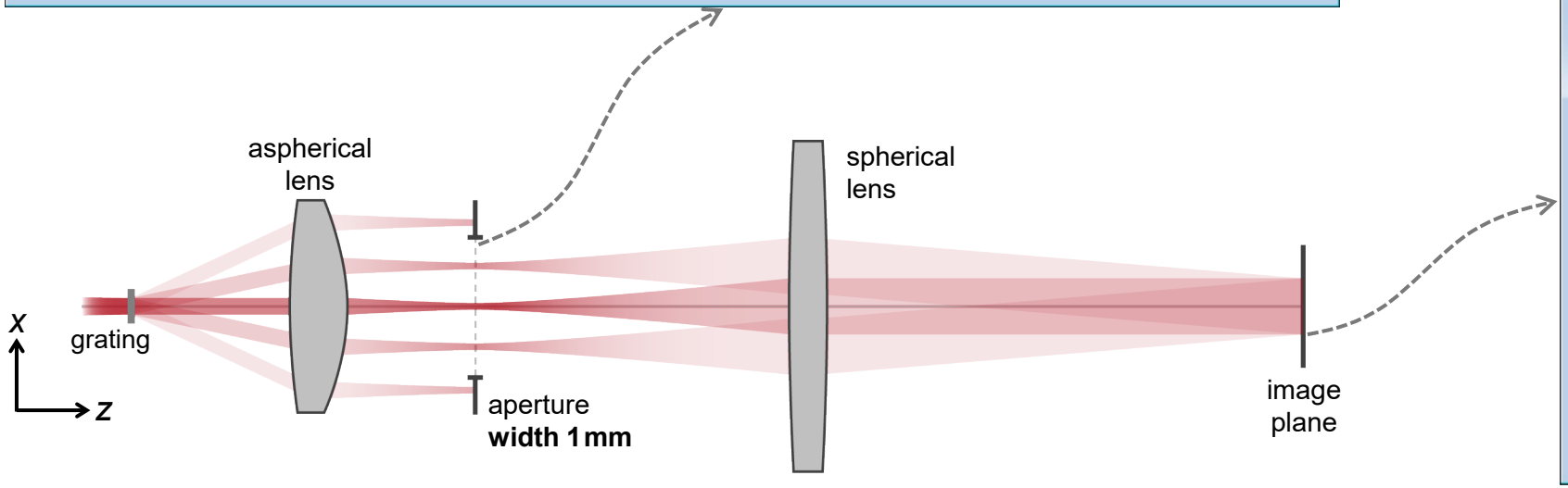


Only the 0th diffraction order passes the aperture.

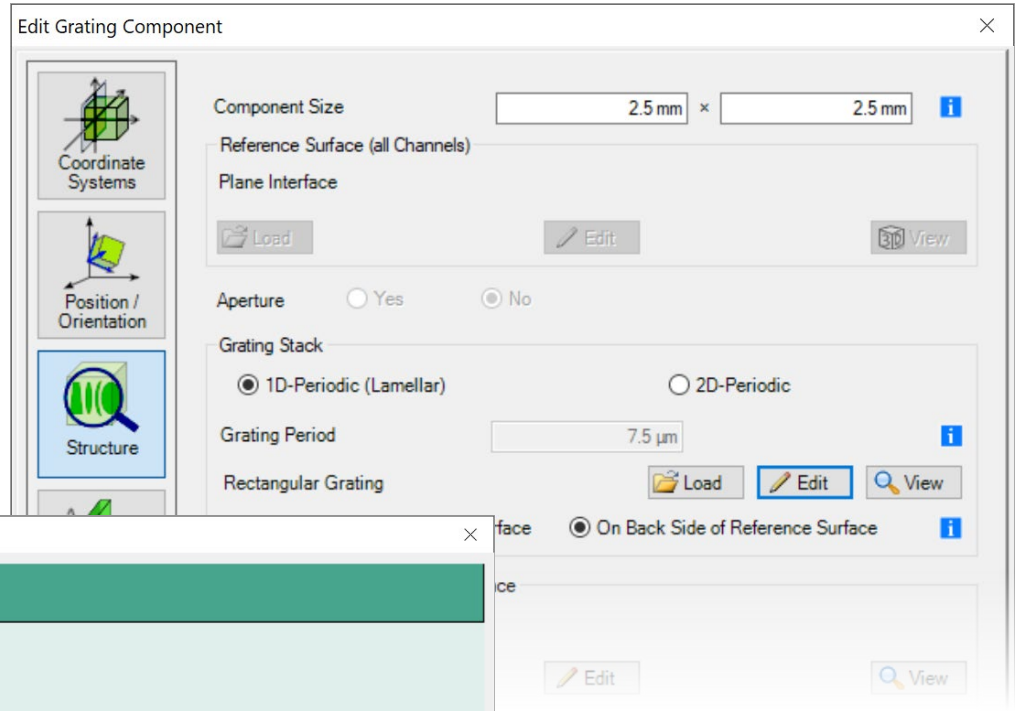


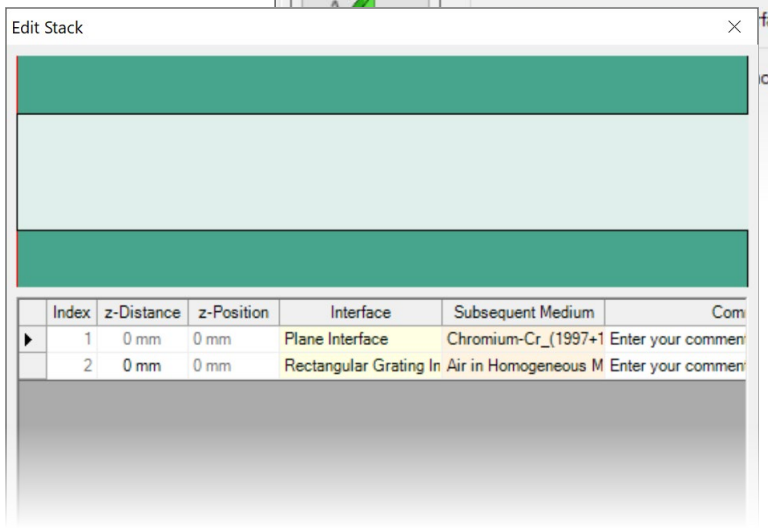
The image is a magnification of the input Gaussian beam.





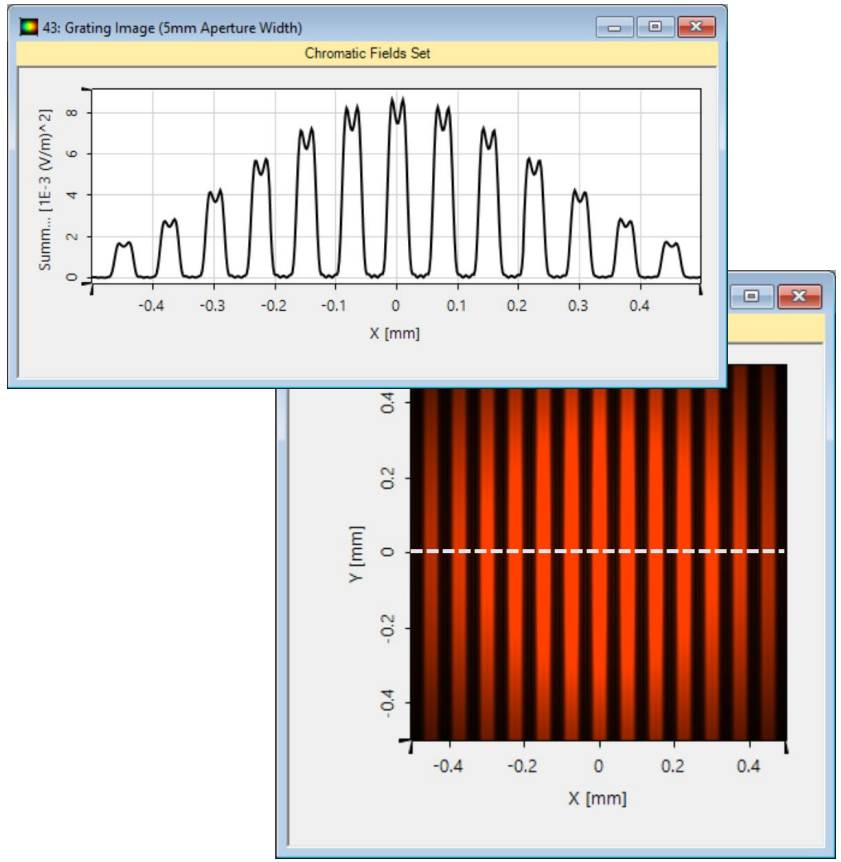
Peek into VirtualLab Fusion





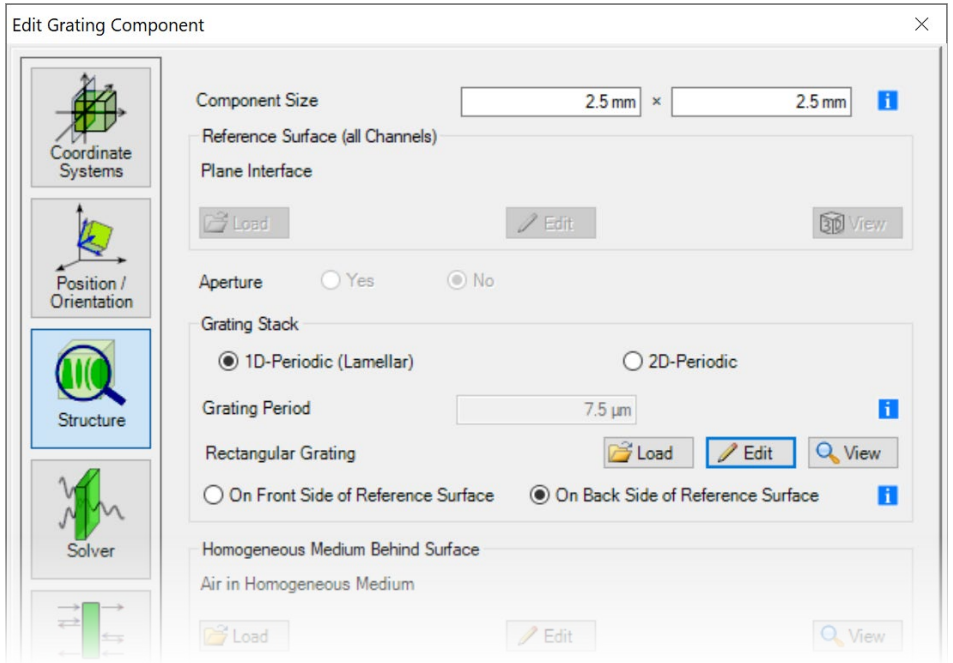
easy inclusion of real gratings into the system modeling

direct and flexible visualization of field quantities in the system

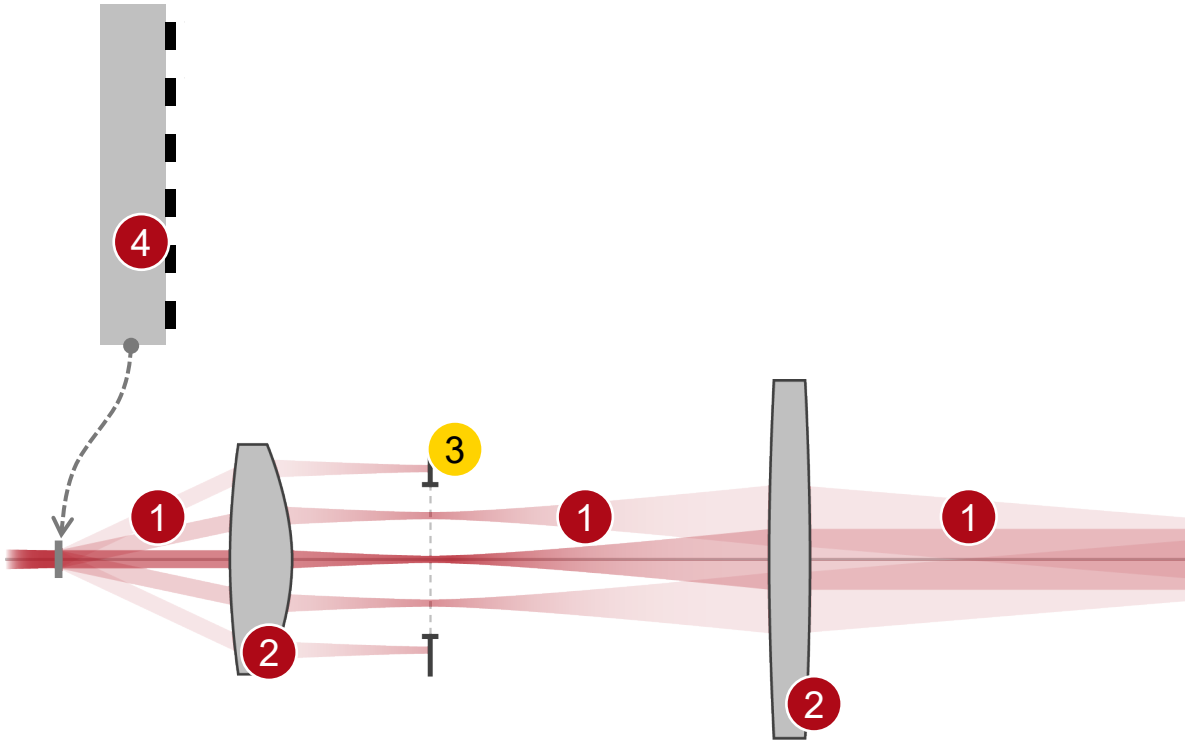


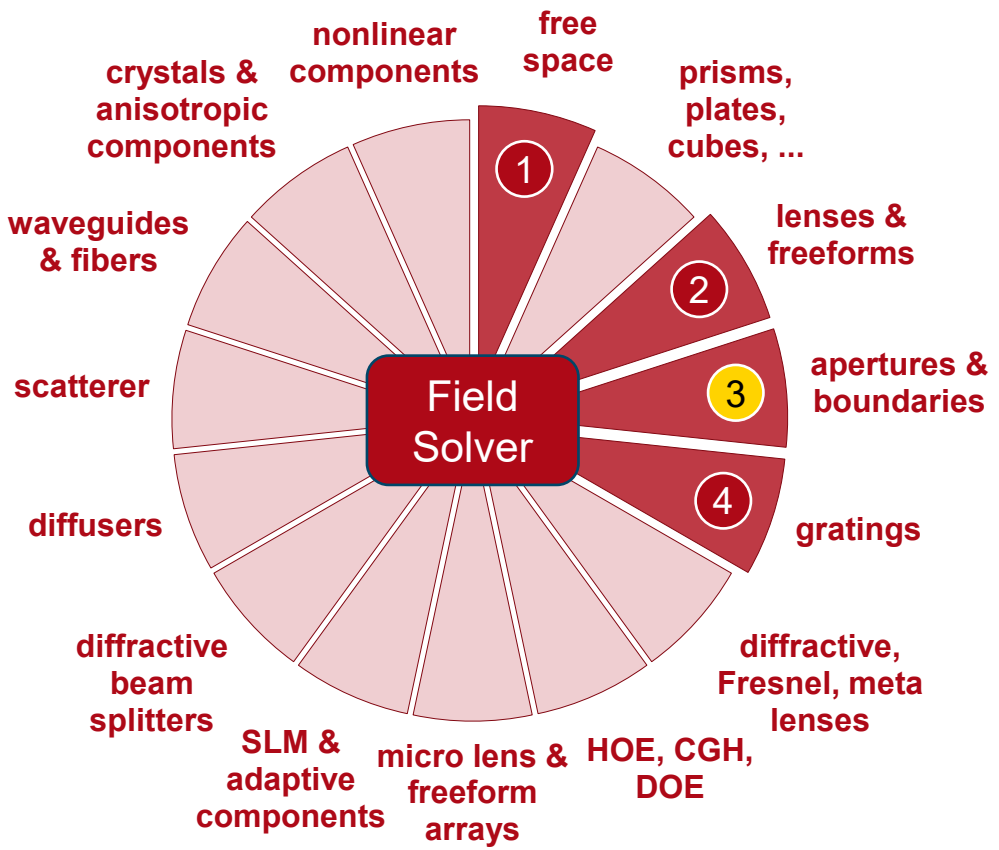
Workflow in VirtualLab Fusion

- Import lens systems from Zemax OpticStudio®
  - Import Optical Systems from Zemax OpticStudio® [Use Case]
- Include grating components into system modeling
- Set the Fourier transforms properly according to the situation



VirtualLab Fusion Technologies





idealized component

Document Information

title	Demonstration of Abbe's Theory of Image Formation
document code	MIC.0009
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software version	2020.1 (Build 2.8)
category	Application Use Case
further reading	- Resolution Investigation for Microscope Objective Lenses by Rayleigh Criterion